# Compact High Efficiency GaN-based PPU, Phase I

Completed Technology Project (2018 - 2019)

## Project Introduction

Busek proposes to develop a low-cost, lightweight Hall Effect Thruster (HET) Power Processing Unit (PPU) at targeted 1kW/kg power density with more than 97% efficiency. The proposed PPU solution adopts advanced GaN power MOSFETs and PCB based planar magnetics technology to enable high switching frequency operation. Reduced headcount of magnetics, semiconductors and associated driver integrated circuits will allow for significant size reduction of all passive components to support ultra-high power density designs. This innovation will further miniaturize HET PPUs from today's state-of-art by an anticipated 30% in volume and mass, with cost reductions exceeding 50% versus SOA solutions.

The unique advantages of the proposed system can be summarized in three parts. First, the system utilizes a novel single-core multi-port circuit topology which integrates all the PPU subsystems through a single stage power conversion using a single multi-winding transformer. This significantly reduces system volume, weight, and cost. Second, the power flow control for each subsystem is fully independent regardless of power stage sharing. Each subsystem has its own phase shift control to regulate the desired output voltage and current. Third, the proposed PPU circuit topology is essentially a soft-switching DC-DC converter which can ensure zero-voltage-switching operation for all the switching devices. The proposal adopts the advanced GaN power MOSFETs and PCB based planar magnetics technology to enable high switching frequency operation, which supports a 30% size reduction of magnetics and other passive components in the high-efficiency and high-power density design.

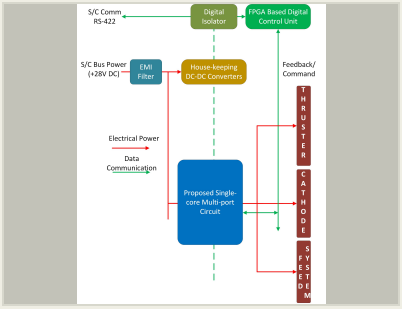
In Phase II Busek will characterize the breadboard PPU with sub-kilowatt Hall thrusters and develop a proto-flight brass-board level unit using GaN devices. At the conclusion of Phase II, Busek will deliver a PPU to NASA for additional characterization testing.

## Anticipated Benefits

HET systems are well suited for interplanetary transfers, supporting exploration and science missions. The Outer Planet Assessment Group identified high power density/high efficiency power electronics for its Titan/Enceladus Flagship and planetary exploration missions. These types of missions, including Mars Sample Return using Hall thrusters and PPUs, require advancements in power electronics. The proposed system meets requirements and is easily scalable, providing greater mission flexibility.

EP systems have been identified as a key technology for transportation of DoD space assets for both orbit transfer and station keeping. The AFRL IHPRPT Program continues to invest in the development of HET systems.

A high power density PPU could also find applications on an all-electric upper

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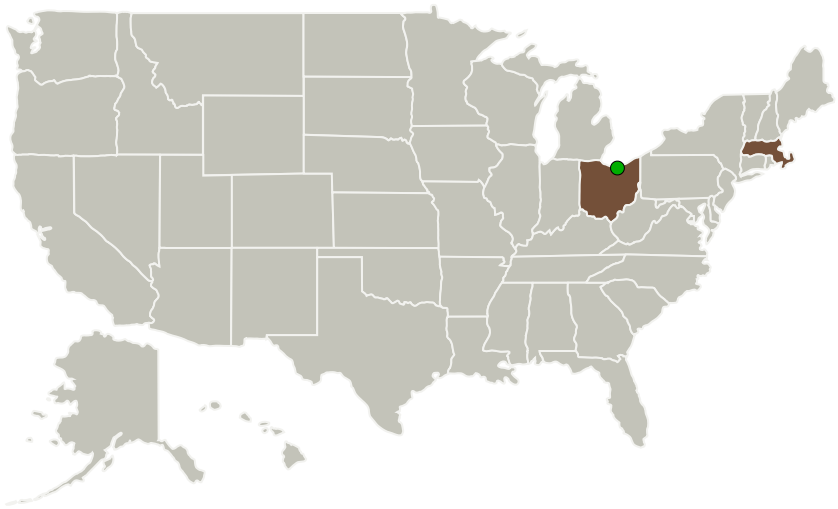
stage derived from Busek/ULA orbit maneuvering system, a free flying S/C based on the ESPA ring.

### Primary U.S. Work Locations and Key Partners



| Organizations Performing Work | Role | Type | Location |
|---|---|---|---|
| Busek Company, Inc. | Lead Organization | Industry<br>Women-Owned Small Business (WOSB) | Natick, Massachusetts |
| Glenn Research Center(GRC) | Supporting Organization | NASA Center | Cleveland, Ohio |

| Primary U.S. Work Locations | |
|---|---|
| Massachusetts | Ohio |

## Organizational Responsibility

**Responsible Mission Directorate:**

Space Technology Mission Directorate (STMD)

**Lead Organization:**

Busek Company, Inc.

**Responsible Program:**

Small Business Innovation Research/Small Business Tech Transfer

## Project Management

**Program Director:**

Jason L Kessler

**Program Manager:**

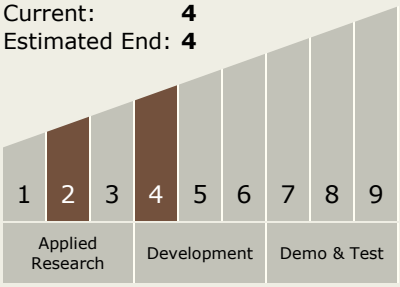
Carlos Torrez

**Principal Investigator:**

Xiaohu Liu

## Technology Maturity (TRL)

Start: **2**
Current: **4**
Estimated End: **4**



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## Project Transitions

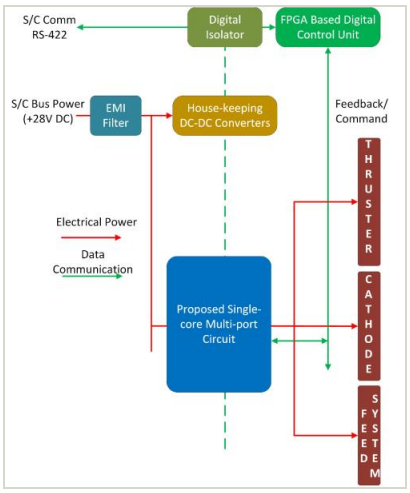
**July 2018:** Project Start

**February 2019:** Closed out

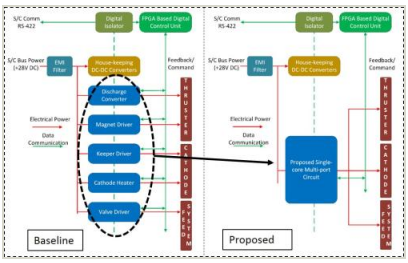
**Closeout Documentation:**

- Final Summary Chart*(https://techport.nasa.gov/file/141310)*

## Images




**Briefing Chart Image**
Compact High Efficiency GaN-based PPU, Phase I
*(https://techport.nasa.gov/image/130505)*




**Final Summary Chart Image**
Compact High Efficiency GaN-based PPU, Phase I
*(https://techport.nasa.gov/image/126307)*

## Technology Areas

**Primary:**

- TX03 Aerospace Power and Energy Storage
  - TX03.3 Power Management and Distribution
    - TX03.3.3 Electrical Power Conversion and Regulation

## Target Destinations

Earth, The Moon, Mars